

AL-TR-1991-0119

AD-A247 823



ARMSTRONG
LABORATORY

**VISUAL ATTENTION AND PERCEPTION IN
THREE-DIMENSIONAL SPACE**

Fred H. Previc
Lisa F. Weinstein

CREW SYSTEMS DIRECTORATE
Brooks Air Force Base, TX 78235-5000

Bruno G. Breitmeyer

University of Houston
Houston, TX 77004

DTIC
ELECTE
MAR 17, 1992
S B D

January 1992

Final Report for Period April 1990 - August 1990

Approved for public release; distribution is unlimited.

92 3 16 123

92-06842



AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5000

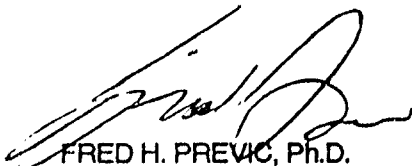
NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

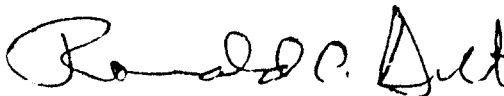
The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.



FRED H. PREVIC, Ph.D.
Project Scientist



RONALD C. HILL, Lt Col, USAF, BSC
Chief, Flight Motion Effects Branch



RICHARD L. MILLER, Ph.D.
Chief, Crew Technology Division

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE January 1992	3. REPORT TYPE AND DATES COVERED Final Report - April 1990 - August 1990	
4. TITLE AND SUBTITLE Visual Attention and Perception in Three-Dimensional Space			5. FUNDING NUMBERS PE - 61101F PR - ILIR TA - VN WU - OC	
6. AUTHOR(S) Fred H. Previc Lisa F. Weinstein Bruno G. Breitmeyer				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Armstrong Laboratory Crew Systems Directorate Brooks Air Force Base, TX 78235-5000			8. PERFORMING ORGANIZATION REPORT NUMBER AL-TR-1991-0119	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES This effort was funded in part through the Laboratory Director's Independent Research (ILIR) Program.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The effects of shifting attention to targets in 3-dimensional (3-D) visual space were investigated. The perceptibility of crossed-disparity (near) and uncrossed-disparity (far) targets located in the upper-left, upper-right, lower-left, and lower-right visual quadrants was measured during attention shifts that were directed by means of centrally presented arrows to the left or right, upper or lower, and near or far fields. Although left-right attention cues produced the expected perceptibility benefits, upper-lower cues produced no benefits and near-far ones produced attentional costs. The effect of shifting attention along the up-down axis using peripheral cues was also investigated; in this case, significant benefits were obtained, especially in the upper visual field. These results and those from basic detectability experiments point to the existence of important inhomogeneities in perceiving and attending to targets in 3-D visual space.				
14. SUBJECT TERMS Three-dimensional space Random-dot stereograms Visual attention Visual perception			15. NUMBER OF PAGES 22	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

TABLE OF CONTENTS

INTRODUCTION	Page 1
METHOD	2
Subjects	2
Stimuli	2
Procedures	3
RESULT	4
Left-Right Attention Effects	4
Upper-Lower Attention Effects	5
Near-Far Attention Effects	6
Neutral-Cue Performance	8
DISCUSSION	9
REFERENCES	10

List of Figures

**Fig.
No.**

- 1** The four sets of cues used in the present study: (a) right-left attention cues; (b) central up-down attention cues; (c) near-far attention cues; and (d) neutral and up-down peripheral attention cues. The near-far cues were also distinguished by slight retinal disparity offsets in the directions in which they pointed. **3**
- 2** Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of the principal octants when left-right arrows were used to cue the location of the target. FL, FU, NL, and NU refer to the far-lower, far-upper, near-lower, and near-upper quadrants, respectively. Solid and diagonalized bars designate the left and right visual fields, respectively. **5**
- 3** Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of the octants when central up-down arrows were used to cue the location of the target. Notation and symbols same as in Figure 2. **6**

**Fig.
No.**

- 4 Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of four quadrants located along the vertical meridian when peripherally located disks were used to cue the location of the target. Notation and symbols same as in Figure 2. 7
- 5 Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of the octants when near-far "arrows" were used to cue the location of the target. Notation and symbols same as in Figure 2. 7
- 6 Mean RT (left panel) and accuracy performance (right panel) in each of the octants for neutral-cue trials. Notation and symbols same as in Figure 2. 8

ACKNOWLEDGMENTS

We extend special thanks to the following individuals for their support of this study: Robert Asteriti (illustrations); Dan Bauer and Joe Fischer (statistical analyses); Drs Marylou Cheal and Art Menendez (theoretical and methodological suggestions); Bev Johnson (computer graphics support); and SSgt Stan Singleton (electronics support). This research was partially supported by: Research Grant ILIR-VNOC from the United States Air Force School of Aerospace Medicine (USAFSAM); a National Research Council Postdoctoral Fellowship to L. Weinstein; and a USAF Summer Faculty Fellowship to B. Breitmeyer.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist. and/or	
Dist.	Special
A-1	

VISUAL ATTENTION AND PERCEPTION IN THREE-DIMENSIONAL SPACE

INTRODUCTION

In a recent theoretical review, Previc (1990) proposed that human visual processing in 3-dimensional (3-D) space is characterized by fundamental nonuniformities. In particular, this theory postulated that the specific links between the upper visual field (UVF) and far vision and between the lower visual field (LVF) and near vision constitute the most striking inhomogeneities in 3-D visual perception. These specific relationships take into consideration both the ecology of our visual environment and the nature of our behavioral interactions within it. For example, the confinement of most visually guided reaching activity to a region lying below the fixated object necessitates a specialized peripersonal visual processing system biased toward the LVF.

In line with Previc's theoretical model, most investigators have shown that crossed-disparity (i.e., near) stimuli are better processed in the LVF, whereas uncrossed-disparity (i.e., far) stimuli are detected more readily in the UVF (Breitmeyer, Julesz & Kropfl, 1975; Breitmeyer, Weinstein & Previc, 1992; Julesz, Breitmeyer & Kropfl, 1976; but see Manning, Finlay, Neill & Frost, 1987). This trend may also interact with an overall advantage for near stimuli (Grabowska, 1983; Harwerth & Boltz, 1979; Lasley, Kivlin, Rich & Flynn, 1984; Mustillo, 1985) and left-right hemifield differences in global depth perception (Breitmeyer et al., 1992; Durnford & Kimura, 1971; Grabowska, 1983; Manning et al., 1987).

A limited amount of evidence also suggests that differences exist in the way humans *attend* to near vs. far visual stimuli. Two studies (Downing & Pinker, 1985; Gawryszewski, Riggio, Rizzolatti & Umiltà, 1987) reported that attention shifts to near targets are more readily performed than are shifts to far targets (which parallels the detectability findings just cited), but a third study concluded that focused attention is biased toward uncrossed-disparity space (Andersen, 1990). All of these studies suffered from methodological limitations, as the cues used to direct attention to near and far space were nonspatial (i.e., alphanumeric) in Downing and Pinker's study and nonveridical (i.e., upper-lower) in Gawryszewski et al.'s study, whereas the near and far stimuli in Andersen's (1990) study were not equated in terms of stereoscopic size and distance from fixation. Nor did any of these studies investigate whether attention to near and far targets is differentially affected by whether the targets appear in the UVF vs. LVF, as predicted by Previc's model.

Consequently, the major objective of our research was to examine the nature of attention shifting in 3-D space using attention cues that were designed to be as veridical and uniform as possible.

METHOD

Subjects

Eight civilian and military employees of the United States Air Force School of Aerospace Medicine (USAFSAM) (now Armstrong Laboratory) served as subjects. The subjects ranged in age from 16 to 42 years. All of these subjects proved capable of discriminating the target stimuli at above-chance levels in all target locations, and they received extensive training before participating in the actual experiment. Four subjects served in both the initial and follow-up experiments, whereas 2 other pairs of subjects served in only 1 of the experiments (each experiment used a total of 6 subjects).

Stimuli

The target stimuli consisted of 2 types of random-dot stereograms (diamonds or squares) presented at equal 3-D distances from a central fixation cross. In the initial experiment, the 30-mm² targets appeared in each of the 8 principal octants of the visual field (near lower left, near lower right, near upper left, near upper right, far lower left, far lower right, far upper left, and far upper right), while in the follow-up experiment the stimuli appeared in 1 of 4 locations along the vertical meridian (near lower, near upper, far lower, and far upper). All target stimuli were located at approximately equal distances (25 mm horizontally and vertically; 23 mm in depth) from the fixation point in 3-D space. The experiment was carried out in the USAFSAM Visual Orientation Laboratory. A detailed description of the target stimuli and their locations, as well as the apparatus used to generate them, is contained in a corollary report (Breitmeyer et al., 1992). Each subject viewed the visual display with his or her head resting on an ophthalmologic head and chin brace. The average viewing distance was 50 cm, although it deviated by as much as 3 cm from this distance in order to take into account each subject's interpupillary distance.

The attention cues used in the initial experiment consisted of a set of arrows that always pointed to the hemifield (either left or right, upper or lower, or near or far) in which the target appeared (see Fig. 1a-c). Although the targets were positioned obliquely relative to the direction of the arrow (which always pointed to the center of the hemifield), it has been shown that fairly uniform attentional benefits occur as long as the target appears in any portion of the attended hemifield (Cheal & Lyon, 1989; Hughes & Zimba, 1987). The "arrows" in the near-far condition (Fig. 1c) were actually wedges that pointed either toward or away from the subject, with their three-dimensionality provided by a combination of appropriate linear perspective, shading, and disparity cues. In addition, a disk whose diameter was 8 mm was used as a neutral cue, which provided no clues as to the location of the subsequent target (Fig. 1d). Both the attentional and neutral cues in the initial experiment were contained within a central 37-mm² fixation area that was free of background dots.

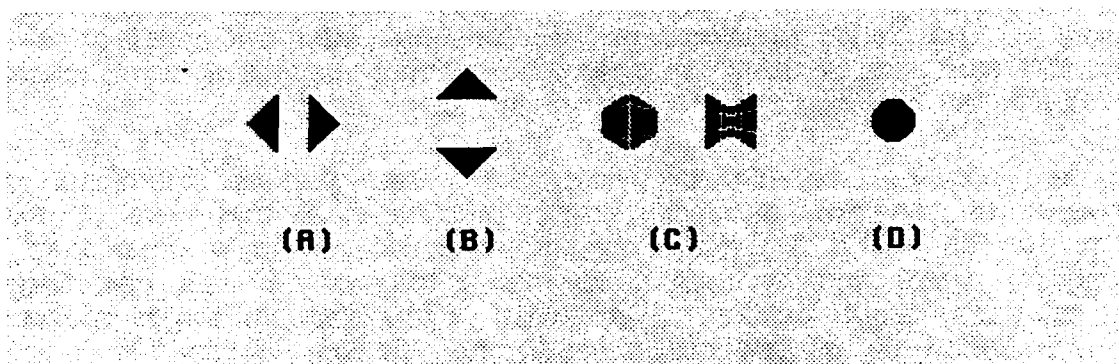


Figure 1. The four sets of cues used in the present study: (a) right-left attention cues; (b) central up-down attention cues; (c) near-far attention cues; and (d) neutral and up-down peripheral attention cues. The near-far cues were also distinguished by slight retinal disparity offsets in the directions in which they pointed.

In the follow-up experiment, the attention cues were identical to the neutral cue in appearance, but were placed in either the upper or lower visual field at the precise vertical location at which the target stimulus appeared (i.e., 25 mm [~ 3 deg] directly above or below the center of the fixation cross).

Procedures

In the initial experiment, each of the 3 attention conditions was run in a separate daily session lasting about 30 min. Each session consisted of six 96-trial blocks, the first of which served as a practice block whose data were later discarded. Thus, data from a total of 480 trials (60 for each target location) were obtained for each attention condition. In each trial block, 32 trials used 1 of the 2 spatial attention cues (e.g., either the leftward or rightward arrows), 32 used the other spatial cue, and the remaining 32 used the neutral cue. Hence, two-thirds of the 12 randomly presented trials per octant in each block were associated with valid cueing and one-third with neutral cueing. At each target location, the square and diamond stereograms were presented equally often.

A trial consisted of the following sequence of events. A fixation cross and its random-dot surround field were presented for 2 s. The fixation stimulus was then replaced by either the attention or neutral cue for 109 ms, which in turn was immediately followed by a 109-ms presentation of the target that triggered a Datum 9300 time-code generator. The combined duration of the cue and target (218 ms) was too brief for saccadic and vergence movements to seriously contaminate the attention results (Hallett, 1986; Heywood & Churcher, 1980; Rashbass & Westheimer, 1961). The target was followed by a 1-s blank screen interval during which subjects responded as quickly and accurately as possible by depressing 1 of 2 designated keys on a computer keyboard with

either the index or middle finger of their right hand. The maximum allowable latency for the choice reaction-time (RT) response after the onset of the target was 650 ms, and all tardy or otherwise incorrect responses were followed by a 156-ms "X" displayed at the end of the blank interval.

The follow-up experiment, which only used vertical attentional cueing, consisted of three 96-trial blocks and a practice block that were all run in a single session. The 8 target locations were reduced to 4 (near lower, near upper, far lower, and far upper), so that a total of 24 trials per block were run for each target location. Two-thirds of the random target presentations were preceded by a disk appearing at the identical vertical location as the target, whereas the other one-third were preceded by the centrally presented neutral cue. Once again, the square and diamond stereograms were presented equally often on a random basis.

The subject's task and the sequence of events in each trial were identical to those just described, except that the duration of the attention cue was increased to 125 ms while the target's duration was reduced to 94 ms. This modification, along with the introduction of a peripheral cue placed at the identical locus as the subsequent target (Cheal & Lyon, 1989, 1991; Jonides, 1981), was designed to enhance the attention effect by increasing the salience of the cue and decreasing the perceptibility of the target. Since the total time allowed for the combined processing of the stimulus was basically the same as before, the likelihood that eye movements seriously contaminated the attention effects remained low.

RESULTS

Since the left-right, upper-lower, and near-far attention manipulations were investigated in separate blocks of trials, individual statistical analyses were performed for each of these conditions. Separate analyses were also carried out for 2 measures of discrimination performance, RT and accuracy (% correct). The attention effects were expressed as the difference between discrimination performance in the attention vs. neutral cue conditions. Negative RT differences indicate that the attention cue produced a benefit by increasing response speed, whereas positive accuracy values indicate that the valid cueing improved identification performance.

Left-Right Attention Effects

The effects of left-right attention cues on RT and accuracy are shown in the left and right graphs of Figure 2, respectively. It is evident from inspection of the left panel that prior knowledge of the lateral hemifield in which the target appeared produced an RT decrease at every target location. The overall mean RT decrease (9.4 ms) proved significant [$t(5)=5.16$, $p < .01$]. No other main or interaction effects for the RT measure were significant.

Inspection of the right panel of Figure 2 reveals that the left-right attention cue produced no overall change in accuracy, thus ruling out the possibility of a speed-accuracy tradeoff. But there was a significant interaction effect involving targets located along the vertical and sagittal (depth) axes [$F(1,5)=7.26$, $p < .05$]. For far targets, left-right attentional cueing yielded increased accuracy in the LVF and decreased accuracy in the UVF; for near targets, the reverse pattern resulted. This interaction may be at least partially attributable to the fact that attentional benefits were greatest in those sectors (e.g., far LVF and near UVF) in which baseline (i.e., neutral-cue) performance was poorest to begin with (see "Neutral-Cue Performance"). No other effects attained statistical significance.

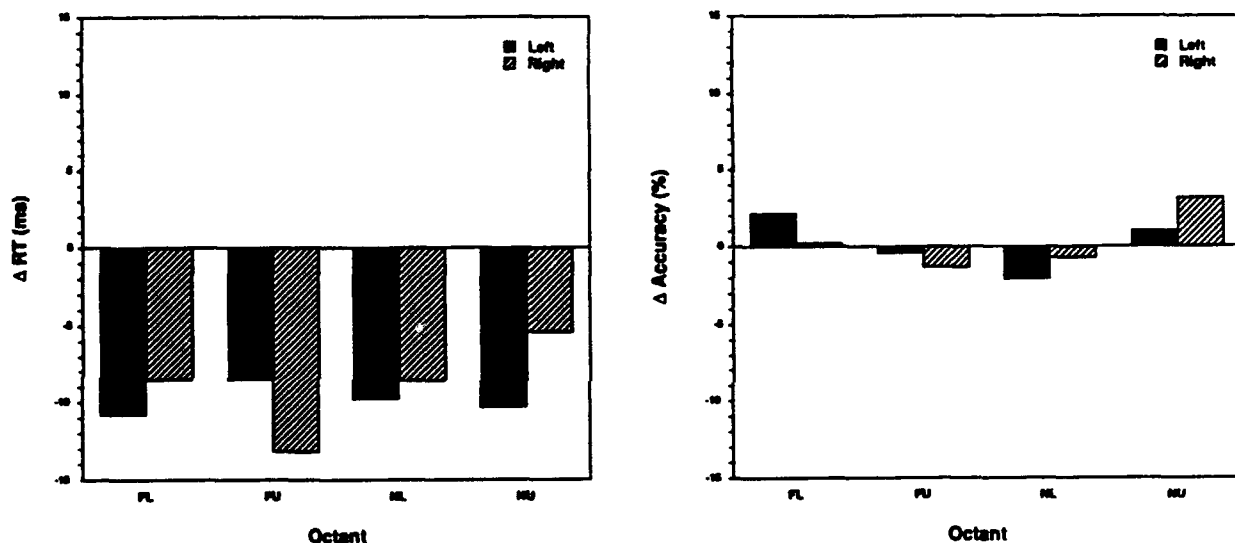


Figure 2. Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of the principal octants when left-right arrows were used to cue the location of the target. FL, FU, NL, and NU refer to the far-lower, far-upper, near-lower, and near-upper quadrants, respectively. Solid and diagonalized bars designate the left and right visual fields, respectively.

Upper-Lower Attention Effects

The effects of upper-lower attention cues on RT and accuracy in the initial experiment are shown in the left and right graphs of Figure 3. The overall attention effect for both measures proved nonsignificant, and there were no other significant main or interaction effects.

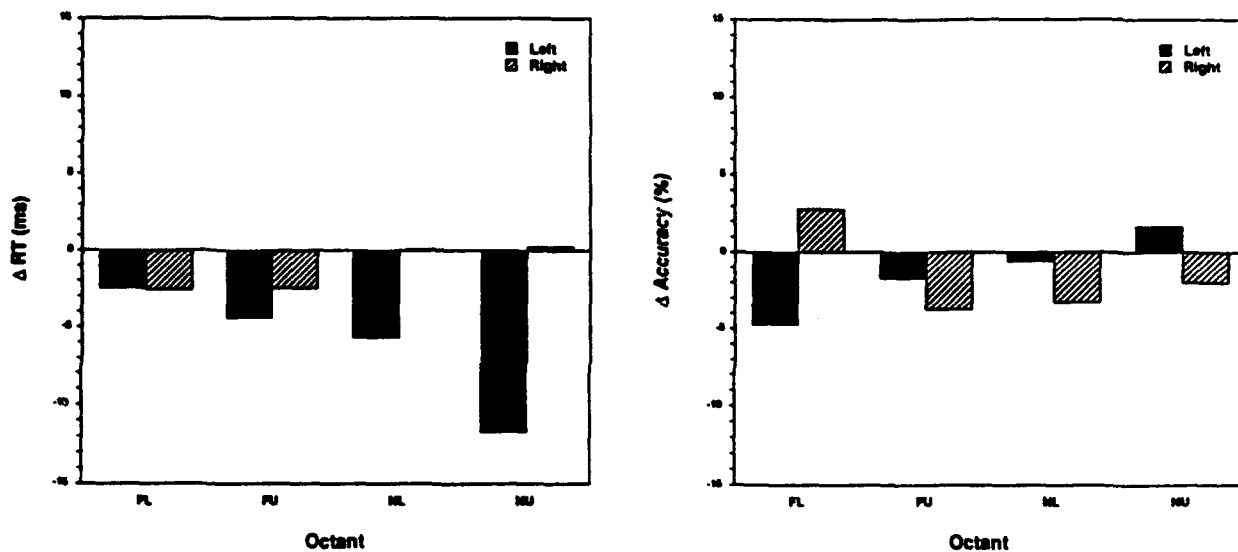


Figure 3. Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of the octants when central up-down arrows were used to cue the location of the target. Notation and symbols same as in Figure 2.

Because vertical cueing provided the most direct test of Previc's notion that attention to the UVF and LVF interacts with the target stimulus' location in depth, a follow-up attempt was made to ensure a vertical attention effect using longer and peripherally located attention cues. The results of this experiment for the RT and accuracy data are shown in the left and right graphs of Figure 4. The main effect of attention proved significant only for the RT measure [$t(5)=-2.9$, $p < .05$], with the valid cue producing an overall mean RT decrease of 19.5 ms. Also, the RT decrease was significantly greater in the UVF as compared to LVF [$F(1,5)=7.51$, $p < .05$], although the predicted difference in the vertical attention effect for near vs. far target locations (i.e., upper-field attention better for far targets, and vice versa) failed to emerge.

Near-Far Attention Effects

The effects of near-far attention cues on RT and accuracy are shown in the left and right graphs of Figure 5. Unlike the other attention conditions, the near-far manipulation resulted in attentional costs (i.e., increased RTs and reduced accuracy). The overall accuracy decrease proved significant [$t(5)=-3.02$, $p < .05$], while the RT increase just failed to attain significance [$t(5)=-2.38$, $p < .07$]. The only other effect of near-far attention that proved significant involved the left vs. right location of the target [$F(1,5)=8.33$, $p < .05$], with the accuracy decrease more pronounced in the right visual field.

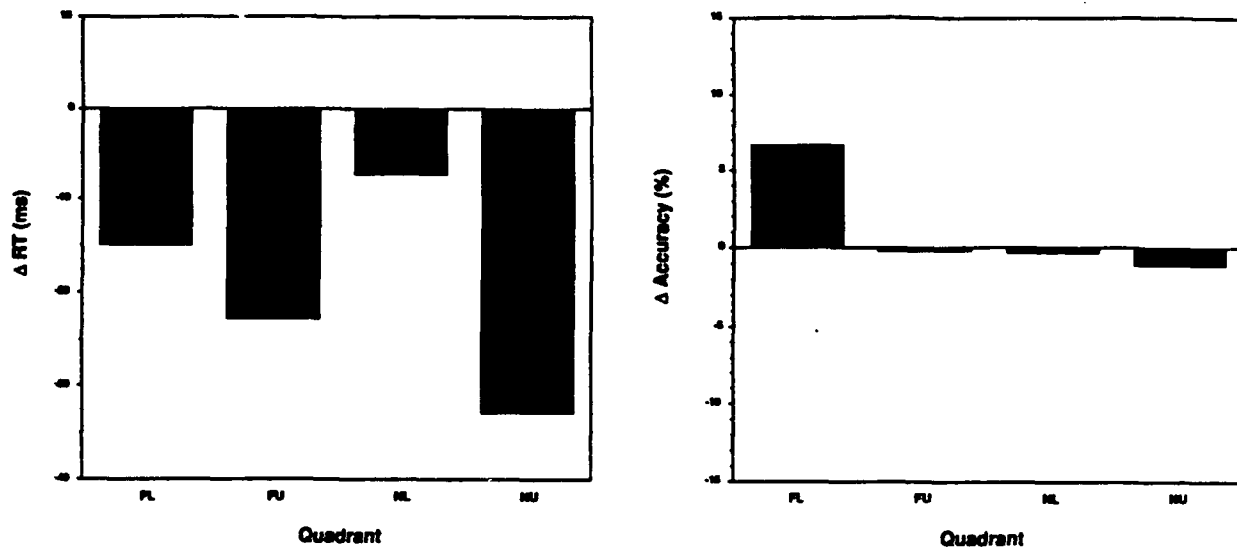


Figure 4. Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of 4 quadrants located along the vertical meridian when peripherally located disks were used to cue the location of the target. Notation and symbols same as in Figure 2.

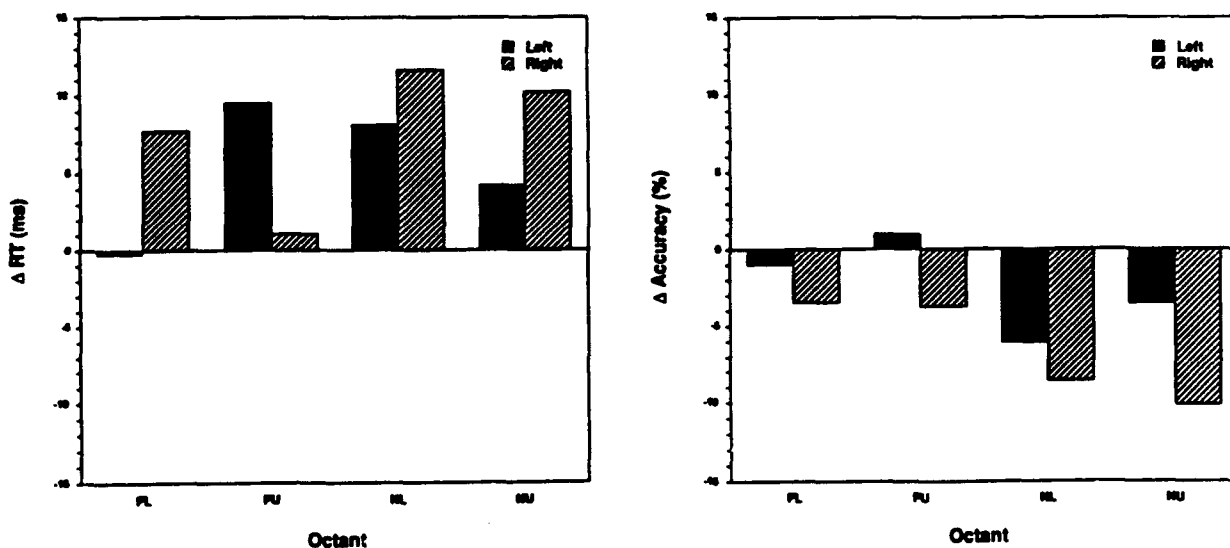


Figure 5. Mean RT differences (left panel) and accuracy differences (right panel) between the attention and neutral trials in each of the octants when near-far "arrows" were used to cue the location of the target. Notation and symbols same as in Figure 2.

Since the near-far attention cues actually interfered with target discrimination performance, no further experiments were conducted to evaluate the proposed interaction between vertical and sagittal attention shifting.

Neutral-Cue Performance

Target discrimination performance across the 8 principal octants of the visual field when a neutral cue preceded the presentation of the target is shown in Figure 6. For the RT data (left panel), the only significant effects were a 3-way interaction among the near-far, upper-lower, and left-right target locations [$F(1,5)=10.52$, $p < .05$] and a 2-way interaction involving the near-far and upper-lower locations [$F(1,5)=24.79$, $p < .01$]. These interactions reflected the reduced mean response latency to near targets in the LVF (518.4 ms) vs. UVF (531.5 ms) and the reverse situation for far targets (512.9 ms in the UVF vs. 521.9 ms in the LVF), as well as the fact that both of the above trends were much more evident in the left visual field than in the right one.

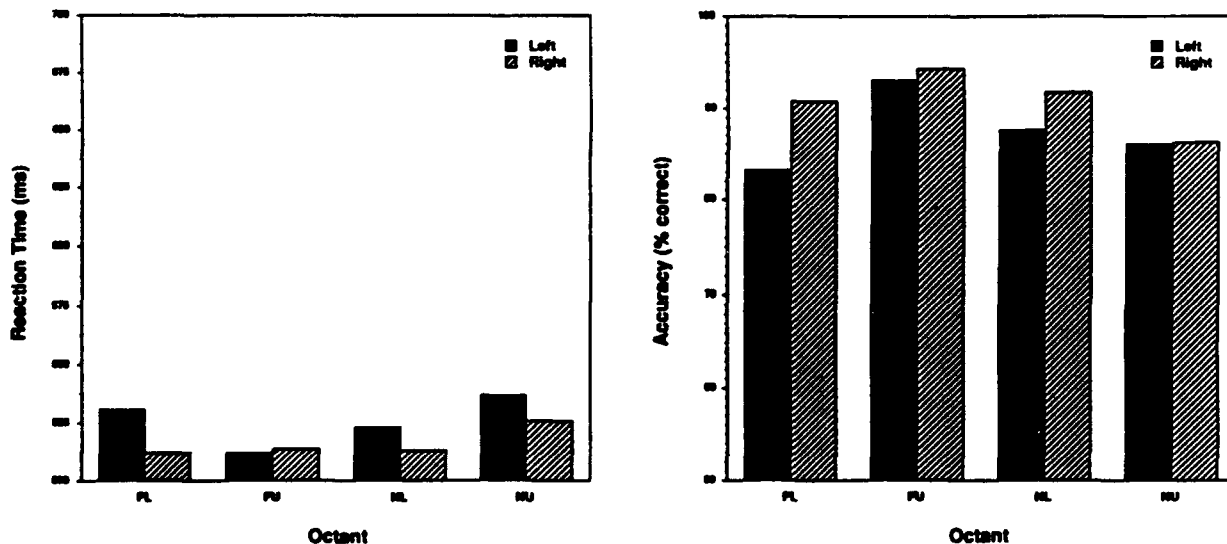


Figure 6. Mean RT (left panel) and accuracy performance (right panel) in each of the octants for neutral-cue trials. Notation and symbols same as in Figure 2.

The 2-way interaction involving the vertical and depth axes also proved significant for the accuracy data [$F(1,5)=14.54$, $p < .05$]. As shown in the right panel of Figure 6, mean accuracy for far targets was greater in the UVF (93.7%) than in the LVF (87%), whereas for near targets it was greater in the LVF (89.7%) than in the UVF (86.2%). A significant main effect involving the

left-right target locations was also obtained [$F(1,5)=7.91$, $p < .05$], which reflected the fact that the overall mean accuracy in the right visual field (90.7%) was superior to that in the left visual field (87.5%). This result, of course, was expected given that the subject's response was made with the right hand, which is controlled by the same hemisphere that receives the direct visual input from the right visual field.*

DISCUSSION

The results of this study are inconclusive as regards the putative interdependencies in shifting attention along the 3 major axes in 3-D visual space. Although significant effects of attention were obtained for left-right central cueing and up-down peripheral cueing, these effects were primarily limited to the particular axis along which attention was shifted.

Although Breitmeyer et al.'s (1992) findings as well as those from the neutral-cue condition in our study indicate that left-right processing differences may interact weakly with the depth and vertical location of the stimulus, the major attentional interactions in Previc's theory are hypothesized to involve the upper-lower and near-far axes. Specifically, we predicted that the benefits of directing attention to the UVF would be limited to far targets, whereas the benefits associated with LVF attention would be limited to near targets. The results of the upper-lower peripheral cueing experiment did not confirm this prediction, however, as the vertical effect was not influenced by the target's location in depth. Indeed, UVF and LVF attention shifts produced benefits for *both* near and far stimuli that were located in the proper vertical location. No clear explanation can be given at this time as to why the predicted attentional interactions were not found, particularly given that target-discrimination performance in the neutral-cue condition did manifest the hypothesized (and previously demonstrated) 3-D interactions. However, it is conceivable that the depth separation (~5 cm) between the crossed- and uncrossed-disparity targets in the present study was adequate for revealing the 3-D *perceptibility* interactions but not the 3-D *attentional* ones.

It is also difficult to explain why benefits were greater overall in the UVF when attention was directed vertically via peripheral cues. Possibly this effect resulted from: (a) the greater salience of the small, brief attention cue when presented above the fixation point, given that similar types of stimuli have been shown to be processed better in the UVF (Chaiken, Corbin & Volkmann, 1962; Previc, 1990; Yund, Efron & Nichols, 1990); (b) the natural tendency to begin our scanning of objects and text in the UVF (Chedru, Leblanc & Lhermitte, 1973; Jeannerod, Gerin & Pernier, 1968); (c) the fact that attention was shifted in conjunction with a pattern-discrimination task, which may involve to a greater extent inferior temporal-lobe processing biased toward the UVF (Previc, 1990);

* The interaction between the near-far and upper-lower target locations also was evidenced in the neutral-cue condition from the follow-up experiment, as would be expected given that most of the subjects in that experiment also served in the initial one.

or (d) a combination of these or some additional factors. While the latencies of saccadic eye movements are shorter to targets in the UVF (Heywood & Churcher, 1980; Previc, 1990), regardless of whether they lie in front or behind the fixation point (Honda & Findlay, 1992), it is unlikely that such movements contaminated our finding given that they are rarely made in similar attention paradigms (Cheal & Lyon, 1991) and could not have been readily made within the brief time allotted by the cue-target stimulus interval (<220 ms). In any case, the finding of greater UVF attentional benefits conflicts with the greater LVF attentional benefits shown in a previous study (Gawryszewski et al., 1987), and consequently requires further investigation.

In contrast to the other attention manipulations, the use of carefully designed near-far spatial cues unexpectedly produced only attentional costs in our study. Apparently the 3-D arrow representations may have been much more difficult to process than the 2-D arrows used in the other conditions and consequently distracted the subject's attention away from the location of the subsequent target. Perhaps attention shifting in depth may only be possible using longer cue durations and a careful monitoring of eye position. In any case, we strongly recommend that future 3-D attention studies use highly similar or even improved versions of the near-far cues used in our study to maximally facilitate comparisons with spatial attention effects along the other 2 major axes, since in our opinion these cues constitute a major improvement over those of previous 3-D attention studies.

REFERENCES

- Andersen, G. J. (1990). Focused attention in three-dimensional space. *Perception and Psychophysics*, 47, 112-120.
- Breitmeyer, B., Julesz, B., & Kropfl, W. (1975). Dynamic random-dot stereograms reveal an up-down anisotropy and a left-right isotropy between cortical hemifields. *Science*, 187, 269-270.
- Breitmeyer, B. G., Weinstein, L. F., & Previc, F. H. (1992). Field differences in the perception of three-dimensional stimuli. *Vision Research* (submitted for publication).
- Chaikin, J. D., Corbin, H. H., & Volkman, J. (1962). Mapping a field of short-time visual search. *Science*, 138, 1327-1328.
- Cheal, M., & Lyon, D. (1989). Attention effects on form discrimination at different eccentricities. *The Quarterly Journal of Experimental Psychology*, 41A, 719-746.
- Cheal, M., & Lyon, D. R. (1991). Central and peripheral precueing of forced-choice discrimination. *The Quarterly Journal of Experimental Psychology*, 43A, 859-880.

- Chedru, F., Leblanc, M., & Lhermitte, F. (1973). Visual searching in normal and brain-damaged subjects (contribution to the study of unilateral inattention). *Cortex*, 9, 94-111.
- Downing, C. J., & Pinker, S. (1985). The spatial structure of visual attention. In M. I. Posner & O. S. Marin (Eds.), *Attention and performance XI* (pp. 171-187). Hillsdale, NJ: Erlbaum.
- Durnford, M., & Kimura, D. (1971). Right hemisphere specialization for depth perception reflected in visual field differences. *Nature*, 231, 394-395.
- Gawryszewski, L. de G., Riggio, L., Rizzolatti, G., & Umiltà, C. (1987). Movements of attention in the three spatial dimensions and the meaning of "neutral" cues. *Neuropsychologia*, 25, 19-29.
- Grabowska, A. (1983). Lateral differences in the detection of stereoscopic depth. *Neuropsychologia*, 21, 249-257.
- Hallett, P. E. (1986). Eye movements. In K. R. Boff, L. Kaufman & J. P. Thomas (Eds.), *Handbook of perception and performance* (Vol. 1) (pp. 10-1-10-112). New York: Wiley & Sons.
- Harwerth, R. S., & Boltz, R. L. (1979). Stereopsis in monkeys using random dot stereograms: The effect of viewing duration. *Vision Research*, 19, 985-991.
- Heywood, S., & Churcher, J. (1980). Structure of the visual array and saccadic latency: Implications for oculomotor control. *Quarterly Journal of Experimental Psychology*, 32, 335-341.
- Honda, H., & Findlay, J. M. (1992). The increase in saccade latencies in the lower visual field. *Perception and Psychophysics* (in press).
- Hughes, H. C., & Zimba, L. D. (1987). Natural boundaries for the spatial spread of directed visual attention. *Neuropsychologia*, 25, 5-18.
- Jeannerod, M., Gerin, P., & Pernier, J. (1968). Déplacements et fixations du regard dans l'exploration libre d'une scène visuelle. *Vision Research*, 8, 81-97.
- Jonides, J. (1981). Voluntary versus automatic control over the mind's eye movement. In J. B. Long & A. D. Baddeley (Eds.), *Attention and performance IX* (pp. 187-203). Hillsdale, NJ: Erlbaum.
- Julesz, B., Breitmeyer, B., & Kropfl, W. (1976). Binocular-disparity-dependent upper-lower hemifield anisotropy and left-right isotropy as revealed by dynamic random-dot stereograms. *Perception*, 5, 129-141.

- Lasley, D. J., Kivlin, J., Rich, L. & Flynn, J. T. (1984). Stereo-discrimination between diplopic images in clinically normal observers. *Investigative Ophthalmology and Visual Science*, 25, 1316-1320.
- Manning, M. L., Finlay, D. C., Neill, R. A., & Frost, B. G. (1987). Detection threshold differences to crossed and uncrossed disparities. *Vision Research*, 27, 1683-1686.
- Mustillo, P. (1985). Binocular mechanisms mediating crossed and uncrossed stereopsis. *Psychological Bulletin*, 97, 187-201.
- Previc, F. H. (1990). Functional specialization in the lower and upper visual fields in humans: Its ecological origins and neurophysiological implications. *Behavioral and Brain Sciences*, 13, 519-542.
- Rashbass, C., & Westheimer, G. (1961). Disjunctive eye movements. *Journal of Physiology*, 159, 339-360.
- Yund, E. W., Efron, R., & Nichols, D. R. (1990). Detectability gradients as a function of target location. *Brain and Cognition*, 12, 1-16.